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ABSTRACT TITLE: Convergence of the effect of root hydraulic functioning and root hydraulic redistribution on ecosystem carbon balance and drought-induced vegetation mortality across divergent forest ecosystems

ABSTRACT: Deep root water uptake and hydraulic redistribution (HR) play a major role in forest ecosystems during drought, but little is known about the impact of climate change on root-zone processes influencing HR and its consequences on drought-induced mortality and on carbon fluxes. Using data from three old growth sites in the western USA, three mature sites in the eastern USA, one site in southern Brazil, and simulations with the process-based model MuSICA, our objectives were to show that HR can 1) mitigate the effects of soil drying on root functioning, 2) reduce tree mortality, and 2) have important implications for carbon uptake and net ecosystem exchange (NEE). In a dry, old-growth ponderosa pine (USA) and a eucalyptus stand (Brazil) both characterized by deep sandy soils, HR limited the decline in root hydraulic failure and tree mortality and increased dry season tree transpiration ($T$) by up to 30%, which impacted NEE through major increases in gross primary productivity (GPP). The presence of deep-rooted trees did not necessarily imply high rates of HR unless soil texture allowed large water potential gradients to occur, as was the case in the wet old-growth Douglas-fir/mixed conifer stand. At the Duke mixed hardwood forest and at the New Mexico piñon /juniper site characterized shallow soils, modeled HR was low but not negligible, representing annually up to 10% of $T$. At this site, in the absence of HR, it was predicted that annual GPP would have been diminished by 7-19%. At the coastal loblolly pine plantation, characterized by deep organic soil, HR limited the decline in root conductivity by more than 50%, prevented tree mortality and increased dry season $T$ by up to 40%. Under future climate conditions (elevated atmospheric [CO$_2$] and temperature), HR is predicted to be reduced by up to 45-50%; reducing the resilience of trees to droughts and increasing mortality. We concluded that the predicted reductions in HR under future climate conditions are expected to play an important regulatory role in land–atmosphere interactions by affecting tree death, whole ecosystem carbon and water balance. We suggest that root distribution should be treated dynamically in response to climate change and that HR and its interactions with rooting depth and soil texture should be implemented in soil–vegetation–atmosphere transfer models.

Keywords: root cavitation, carbon sequestration, drought-induced root failure, hydraulic redistribution, MuSICA Model, night transpiration, root conductivity, soil water content